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Findings from The United States
Navy–Marine Corps Combat
Trauma Registry***

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Traumatic brain injury during Operation Iraqi Freedom: findings from the United States Navy–Marine Corps Combat Trauma Registry

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Object. The purpose of this study was to characterize traumatic brain injuries (TBIs) among military personnel (primarily Marines) during the second phase of Operation Iraqi Freedom from early in the medical care chain of evacuation through Landstuhl Regional Medical Center, a Level 4 American hospital in Germany.

Methods. Data were obtained from the Navy–Marine Corps Combat Trauma Registry (CTR) and included both battle and nonbattle injuries. Follow-up of patients with TBI was conducted to examine the short-term medical and personnel-related effects of TBI among those surviving.

Results. Those injured in battle were more likely than those not injured in battle to have multiple TBI diagnoses, a greater number of all diagnoses, more severe TBIs, and to be medically evacuated. Intracranial injuries (for example, concussions) were the predominant type of TBI, although skull fractures and open head wounds were also seen. Improvised explosive devices were the most common cause of TBIs among battle injuries; blunt trauma and motor vehicle crashes were the most common causes among nonbattle injuries. Short-term follow-up of surviving patients with TBI indicated higher morbidity and medical utilization among the patients with more severe TBI, although mental conditions were higher among patients with milder TBI.

Conclusions. Data from the Navy–Marine Corps CTR provide useful information about combatants' TBIs identified early in the combat casualty process. Results may improve clinical care for those affected and suggest strategies for primary prevention. The CTR staff plans to conduct additional follow-up studies of this group of patients with TBI.

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KEY WORDS • Navy–Marine Corps Combat Trauma Registry • Operation Iraqi Freedom • traumatic brain injury

TRAUMATIC brain injury is a nondegenerative, noncongenital injury to the head arising from blunt or penetrating trauma or from acceleration/deceleration forces. Specifically, a head injury is defined as a TBI when there is a decreased level of consciousness, amnesia, a skull fracture, objective neurological or neuropsychological abnormality, a diagnosed intracranial lesion, or when death occurs as a consequence of head injury. Consequences among survivors can be mild, moderate, or severe, and can range from physical disabilities to long-term cognitive, behavioral, and social deficits. The direct and indirect costs

of TBI in the US are staggering—an estimated \$56 billion each year.²⁰

Among civilians (and active-duty military during peacetime) the leading causes of TBI are motor vehicle crashes, interpersonal violence, and falls.^{5,15} Disabilities resulting from TBI depend on the injury severity, location of the injury, age, and general health of the individual, although many people who sustain even a moderate TBI can experience significant physical, behavioral/psychiatric, cognitive, and medical problems.¹⁷

From a combat perspective, the risk of TBI is considerable given the exposure and vulnerability of the head⁴ and the changing nature of warfare. Soldiers in the 21st century, although far better equipped to protect themselves from injuries caused by bullets and bombs, are at risk from blast injuries caused by IEDs, rocket-propelled grenades, and land mines. Although it is not known for certain how often blasts result in brain injuries, descriptive studies estimate that the rate may be ~ 60%.^{6,18} In previous conflicts, ~ 20% of all casualties were due to brain injuries, although the occurrence among troops currently serving in the Middle East

Abbreviations used in this paper: AIS = Abbreviated Injury Scale; CHAMPS = Career History Archival Medical and Personnel System; CTR = Combat Trauma Registry; ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification; IED = improvised explosive device; ISS = Injury Severity Score; MTF = medical treatment facility; OIF2 = Operation Iraqi Freedom, second phase; PTSD = posttraumatic stress disorder; TBI = traumatic brain injury.

may be higher than in previous conflicts.^{14,19} So prevalent is this type of injury that some consider it the “signature wound” of the Iraq war, much like Agent Orange exposure in the Vietnam War.¹³

Because head wounds and TBI account for high rates of mortality and morbidity during combat and afterward, these types of injury warrant special attention. More information is needed about the characteristics of TBI among those serving in Iraq, the conditions surrounding this type of injury, and the outcomes of such injuries. The purpose of this study was to describe TBIs among military personnel (primarily Marines) during OIF2, beginning early in the medical care chain of evacuation using data from the Navy–Marine Corps CTR. In addition, follow-up of patients with TBI was conducted to examine the short-term medical and personnel-related effects of TBI among survivors. Information about the characteristics of the TBI combat casualty population beginning near the point of injury and the early effects of the injury may help improve clinical care and suggest strategies for primary prevention.

Clinical Materials and Methods

Setting and Procedures

The patients in this study presented to forward MTFs (that is, facilities that provide immediate triage and stabilization of patients) during the stability and support phase of OIF2, defined here as the 7-month period between March 2004 and September 2004. Data were collected at MTFs (that is, Level 1 and 2 facilities) dispersed throughout the Navy–Marine Corps area of responsibility in Iraq, including battalion aid stations, forward resuscitative surgery system facilities, and 2 surgical companies. These facilities provided initial resuscitative intervention, damage control surgical procedures, additional medical assessment, and stabilization for evacuation. An article by Bagg and colleagues¹ is useful for understanding the sophisticated levels of trauma care in Iraq. There are 5 levels, or echelons, of care, each progressively more advanced. Level 1 care provides immediate first aid at the front line. Level 2 care consists of surgical resuscitation provided by highly mobile forward surgical teams that directly support combatant units in the field. Level 3 care is provided through combat support hospitals—large facilities that take time to become fully operational but offer much more advanced medical, surgical, and trauma care, similar to a civilian trauma center. Level 4 care is the first echelon at which definitive surgical treatment is provided outside the combat zone. Level 5 care is the final stage of evacuation to one of the major military centers in the US, where definitive stabilization, reconstruction, or amputation is performed.

Personnel at the medical treatment facilities described in the present study are similar to teams on staff at civilian trauma centers. Each MTF has a full trauma team, including emergency department and critical care doctors, general surgeons, anesthesiologists, physician assistants, and nurses. Orthopedic surgeons, psychiatrists, and other mental health professionals also are available at some of the facilities. Full neurosurgical evaluation, however, must be done at a higher level of care, typically Level 3. Once the patient is stabilized by the trauma team at the Level 2 facility, travel time via air may take 15–45 minutes (depending

on location) to reach definitive neurological care and computed tomography scan capability.

Clinical data for the present study came from medical encounter forms currently in use at forward MTFs in Iraq, as well as clinical records from US Army Level 3 theater hospitals, and the Level 4 American Hospital at Landstuhl Regional Medical Center in Germany. The encounter form captures demographic and various types of clinical information (for example, trauma, disease, nonbattle injury, psychiatric, and routine dental examination data) to populate the Navy–Marine Corps CTR. One purpose of the registry is to analyze combat injury patterns (particularly near the point of injury) and casualty management for wounded Marines and Navy personnel throughout the medical chain of evacuation (see Galarneau et al.⁷ for a detailed description of the Navy–Marine Corps CTR). Encounter forms are completed either on paper or electronically by health care providers in the combat theater, and forwarded to the Navy–Marine Corps CTR at the Naval Health Research Center, in San Diego, California, on an ongoing basis.

Diagnosis of TBI

Navy–Marine Corps CTR clinical staff at Naval Health Research Center read narrative fields from the encounter form that were written by the providers in the combat theater and, in the case of evacuated patients, from clinical records completed at subsequent levels of care (that is, Army Level 3 MTFs and Landstuhl Regional Medical Center, Germany). The narrative fields (for example, SOAP [subjective, objective, assessment, and plan] notes, operating room reports, and imaging studies such as x-ray films, computed tomography scans, and magnetic resonance images) typically described the injury in detail, as well as the circumstances surrounding the injury. For every injury described, the registry staff assigned a diagnostic code based on the ICD-9-CM version 2005. Attempts were made to code to the highest degree of specificity (using the fourth or fifth digit). Based on a standard case definition, cases with ICD-9-CM codes of 800.0–801.9 (fractures of the vault or base of the skull), 803.0–804.9 (other and unqualified and multiple fractures of the skull), 850.0–854.1 (intracranial injury, including concussion, contusion, laceration, and hemorrhage), and 873.0–873.9 (other open wound of the head) were included as TBI cases.²¹ Patients often had multiple ICD-9-CM codes; therefore, any code falling within the TBI case definition qualified the patient for inclusion. In addition to the ICD-9-CM codes, supplemental external cause of injury codes (E codes) were assigned, based on information in the narrative field (ICD-9-CM codes). The E codes are intended to capture information about how the injury happened.

Descriptors of TBI

Several variables were used to describe patients with TBI. An important descriptive measure recorded on the encounter form was casualty type. Registry clinical staff at the Naval Health Research Center again used the narrative field to determine if the casualty was a battle injury, defined as TBI as a direct result of hostile action, or a nonbattle injury, defined as TBI not due to hostile action. Battle injury casualties were further categorized as 1 of the following: wounded in action (those who survived wounds sustained

in action), killed in action (those who were killed during a combat operation), or died of wounds (those who died of wounds received in action following treatment). Because the Navy–Marine Corps CTR primarily collects data for casualties surviving at least until treatment at the first MTF, numbers of individuals killed in action are small and are not meant to reflect actual killed-in-action incidence totals. Therefore, those who were killed in action and died of wounds were combined into a single, combat-related fatalities category for the present study. Other descriptive measures taken directly from the encounter form included mechanism of injury (for example, IED or gunshot), source of injury (for example, enemy or sports injury), type of protective gear worn at the time of injury, final disposition of patient (for example, returned to duty or evacuated), date of birth or age, and sex.

The severity of patients' injuries was described using 2 standardized measures of injury classification and severity assigned by trained Navy–Marine Corps CTR staff. These measures included AIS scores⁸ (injury-specific scores based on an anatomical description of the injury, with scores ranging from 1 [relatively minor] to 6 [currently untreatable]), and ISSs^{2,3} (an overall measure of severity [with scores ranging from 0 to 75], derived from AIS scores in 6 body regions: head, face, chest, abdomen, extremities, and external).

Follow-Up Data

To assess the relatively short-term personnel-related (type of discharge or demotion) and medical outcomes among patients with TBI surviving 30 days postinjury, patients were matched against the CHAMPS database. CHAMPS—maintained by the Naval Health Research Center—contains information on all enlisted members on active duty in the US Armed Forces since 1973 (see Gunderson et al.¹⁰ for a detailed description of CHAMPS). This database is a combination of personnel records from the Bureau of Personnel and medical data from the Navy Medical Information Management Center. At the time of the extract, CHAMPS data were current through August 2005; therefore, the follow-up period for patients with TBI ranged from 12 to 18 months postinjury.

Variables extracted or computed from CHAMPS data included postinjury attrition/discharge information, including reason for discharge; inpatient hospitalization variables, including number of admissions, bed days, and number of diagnoses; and outpatient visit characteristics, including number of visits, and number and type of outpatient diagnoses. Because TBI can be associated with work-related and psychosocial outcomes among military personnel,¹⁶ several social and military performance-related variables were also extracted, including demotions, desertions, absences without leave, and divorce.

Statistical Analysis

Analyses were primarily descriptive, including frequency distributions, measures of central tendency, and cross-tabulations. The TBI characteristics are typically described for the overall group and by casualty type. Personnel and medical follow-up characteristics are presented overall and by level of TBI severity. When sample sizes allowed, we conducted statistical tests (analysis of variance and inde-

pendent group t-tests for differences between means, and chi-square analysis for differences between proportions). These tests and their significance levels help researchers decide whether differences between groups are real or likely due to chance. More information about using and interpreting medical statistics may be found in Matthews and Farewell.¹²

Results

A total of 115 patients with TBI were identified from the Navy–Marine Corps CTR from March through September 2004. These 115 patients received ~ 200 TBI-related diagnoses. Of the 115 patients 89% were Marines, 8% were Army personnel, and 3% were Navy personnel. About 91% of patients with TBI were enlisted personnel, 2% were officers, and 7% were missing enlisted/officer status. All but 1 patient were men (the woman was an enlisted Marine who was injured in a fall). Analysis of age or date of birth, available for approximately two thirds of patients with TBI, revealed a mean age of 24 years (range 19–48 years).

The majority (71%) of the 115 TBI diagnoses were among individuals wounded in action, 16% were nonbattle injuries, and 13% were among those who were killed in action/died of wounds. Table 1 presents the mean number of TBI and non-TBI diagnoses overall and by casualty type. Differences between mean and median number of diagnoses were due to a few patients with an unusually high number of diagnoses. The mean number of diagnoses overall was 4.25 (range 1–27). The mean number of non-TBI diagnoses was 2.53 overall (range 0–23), and the mean number of TBI-related diagnoses was 1.72 (range 1–9). Means and medians generally suggested that individuals wounded in action had a greater number of diagnoses than those with nonbattle injuries and those killed in action/died of wounds ($F_{2,112} = 2.66$, $p = 0.07$). The TBI ICD-9-CM codes grouped into broad categories (see Table 1) showed that intracranial injuries, particularly concussions, were the most common diagnosis category, especially among patients with nonbattle injuries (94%). Skull fractures and other open wounds of the head also were important contributors for those wounded in action and killed in action/died of wounds (26–33%). Although multiple TBI-related diagnoses were common, 51% of the patient group had only an intracranial injury with no accompanying head fracture or open wound of the head. According to E-coding, the majority (93%) of TBIs were caused by war operations, and 7% were vehicle related. Frequently assigned non-TBI diagnoses were often related to the TBI. For example, the most common non-TBI diagnosis, fractures of the facial bones, was present in 11% of patients. There was a tendency for patients with nonbattle injuries to be more likely than those wounded in action to have a combination of TBI and non-TBI diagnoses, although the differences were not statistically significant.

Table 2 presents the mechanism of injury for TBI cases overall and by casualty type. Improvised explosive devices were the most common mechanism of injury responsible for TBI cases overall (52%), among those wounded in action (63%), and those killed in action/died of wounds (53%). Gunshots and mortar blasts each were responsible for ~ 7–9% of TBI cases overall and among those wounded in action; however, these 2 mechanisms were associated

TABLE 1
The ICD-9-CM code information overall and by casualty type*

Measure	Value			
	Overall (115 patients)	WIA (82 patients)	NBI (18 patients)	KIA/DOW (15 patients)
mean (median) no. of ICD-9-CM codes	4.25 (3.0)	4.87 (3.0)	2.72 (2.5)	2.67 (2.0)
mean (median) no. of non-TBI ICD-9-CM codes	2.53 (1.0)	2.95 (2.0)	1.50 (1.0)	1.47 (1.0)
mean (median) no. of TBI ICD-9-CM codes	1.72 (1.0)	1.92 (1.0)	1.22 (1.0)	1.20 (1.0)
broad TBI categories†				
fracture of vault or base of skull (codes 800.0–801.9)	26 (23)	21 (26)	0 (0)	5 (33)
other fractures of the skull (codes 803.0–804.9)	0 (0)	0 (0)	0 (0)	0 (0)
intracranial injury, including concussion (codes 850.0–854.1)	89 (77)	65 (79)	17 (94)	7 (47)
other open wound of head (codes 873.0–873.9)	33 (29)	24 (29)	5 (28)	4 (27)

* KIA/DOW = killed in action/died of wounds; NBI = nonbattle injury; WIA = wounded in action.

† Data are presented as the number of cases (%). Percentages do not equal 100 because patients could have multiple TBI diagnoses. Multiple diagnoses within a category were only counted once.

with TBI in 40% of individuals who were killed in action/died of wounds. Blunt trauma and motor vehicle crashes accounted for > 65% of the nonbattle injuries. Table 2 also presents source of injury. Enemy attack was responsible for all TBIs among those killed in action/died of wounds, and all those wounded in action when the source of injury was recorded. Of note, mechanism and source of injury data were missing for 6–8% of TBI cases overall. Patients with nonbattle injuries in particular had a large amount of missing information about the mechanism (17%) and source (28%) of injury.

As shown in Table 3, the mean overall severity score (ISS) was 11, corresponding to a moderately severe injury. The ISSs varied significantly by casualty type ($F_{2,104} = 31.65$, $p < 0.001$) as one would expect, with individuals who were killed in action/died of wounds having a mean score corresponding to maximal injury. With regard specif-

ically to head injury severity, an AIS score of 2.3 indicated moderate severity, although AIS scores varied by casualty type ($F_{2,103} = 25.58$, $p > 0.001$). Patients with nonbattle injuries had the lowest AIS scores (minor to moderate), those who were killed in action/died of wounds had the highest (critical) scores, and those who were wounded in action had intermediate (moderate) scores. Patients often had AIS scores applied to other body regions, indicating multiple injuries. Fifty percent of TBI patients had Face AIS scores, and 31% received an Extremities AIS score. Neck, Thorax, and Abdomen AIS scores were each coded for 6% of patients, and External AIS scores were assigned to 4%.

Disposition of TBI cases also are shown in Table 3. Equal proportions of patients with TBI overall were evacuated to Level 3 or higher (43%), as were those who returned to duty from Level 1 or Level 2 MTFs (43%). This distribution varied by casualty type, with a relatively higher pro-

TABLE 2
Primary mechanism and source of injury for TBI cases overall and by casualty type*

Injury	No. of Patients (%)			
	Overall (115 patients)	WIA (82 patients)	NBI (18 patients)	KIA/DOW (15 patients)
mechanism				
IED	60 (52.2)	52 (63.4)	0 (0.0)	8 (53.3)
gunshot wound	10 (8.7)	6 (7.3)	0 (0.0)	4 (26.7)
mortar	9 (7.8)	7 (8.5)	0 (0.0)	2 (13.3)
blunt object NOS	6 (5.2)	0 (0.0)	6 (33.3)	0 (0.0)
motor vehicle crash	6 (5.2)	0 (0.0)	6 (33.3)	0 (0.0)
mine	5 (4.3)	5 (6.1)	0 (0.0)	0 (0.0)
blast/fragments NOS	5 (4.3)	4 (4.9)	0 (0.0)	1 (6.7)
rocket-propelled grenade	3 (2.6)	3 (3.7)	0 (0.0)	0 (0.0)
fall	2 (1.7)	0 (0.0)	2 (11.1)	0 (0.0)
crush	1 (0.9)	0 (0.0)	1 (5.6)	0 (0.0)
grenade	1 (0.9)	1 (1.2)	0 (0.0)	0 (0.0)
other/unknown	7 (6.1)	4 (4.9)	3 (16.7)	0 (0.0)
source				
enemy	93 (80.1)	78 (95.1)	2 (11.1)	15 (100.0)
other	8 (7.0)	0 (0.0)	6 (33.3)	0 (0.0)
self-accident	3 (2.6)	0 (0.0)	3 (16.7)	0 (0.0)
sports injury	2 (1.7)	0 (0.0)	2 (11.1)	0 (0.0)
not recorded	9 (7.8)	4 (4.9)	5 (27.8)	0 (0.0)

* NOS = not otherwise specified.

TABLE 3

*Injury severity and disposition overall and by casualty type**

Measure	Value			
	Overall (115 patients)	WIA (82 patients)	NBI (18 patients)	KIA/DOW (15 patients)
mean severity score				
ISS [†]	11.1	9.2	3.5	39.1
highest AIS (head) [‡]	2.3	2.2	1.4	4.8
disposition [§]				
medically evacuated	50 (43)	44 (54)	6 (33)	0 (0)
RTD	50 (43)	38 (46)	12 (67)	0 (0)
KIA/DOW	15 (13)	0 (0)	0 (0)	15 (100)

* RTD = returned to duty.

[†] Eight patients were missing ISSs.[‡] Injuries coded AIS = 9 were removed from analysis.[§] Data are presented as the number of patients (%).

portion of patients sustaining nonbattle injury returning to duty, and a relatively higher proportion of those wounded in action being evacuated. Disposition was strongly related to injury severity. Compared with those who returned to duty, those who were evacuated had significantly higher ISSs—3.5 and 12.0, respectively ($t_{91} = -5.051$, $p < 0.001$). Similarly, evacuated patients cases had higher head-specific AIS scores (2.5) than those who returned to duty (1.5) ($t_{91} = -4.796$, $p < 0.001$).

Table 4 presents information about personal protective gear reported being worn at the time of presentation to the MTF for all TBI cases combined, and by casualty type. Helmets, flak vests, and ceramic plates were worn by about two thirds of patients who sustained TBIs, whereas eyewear was worn less frequently. Of interest is the high percentage of cases in which the use of protective gear (particularly eyewear) was unknown or unrecorded. It is conceivable that equipment may have been blown off or destroyed at the time of injury for some of these casualties. Statistical tests could not be conducted on the percentages of individuals wearing equipment because the data did not satisfy assumptions that must be met to render the test appropriate and reliable. However, a pattern emerged whereby a higher percentage of individuals wounded in action (compared with those who sustained nonbattle injuries and those who were killed in action/died of wounds) were reported to have been wearing protective gear at the time of injury. Individuals typically were wearing > 1 type (mean 2.5 types overall) of protective equipment. Individuals who were wounded in action wore a significantly greater number of types of equipment than those who sustained nonbattle injuries and those who were killed in action/died of their wounds ($F_{2,112} = 7.90$, $p = 0.001$).

Follow-Up of Patients With TBI

Sixty-nine percent of surviving patients matched to CHAMPS. Table 5 presents personnel and medical postinjury variables for the 69 patients with TBI who underwent follow-up overall, and by TBI severity category. Based loosely on definitions used elsewhere,¹⁶ mild TBI was defined as a Head AIS score of 1–2, and moderate to severe TBI was defined as a head AIS score of 3–5. For some of the medical/personnel variables, both mean and median values are presented because of their skewed distributions.

TABLE 4

*Personal protective equipment use at time of injury for TBI cases overall and by casualty type**

Equipment	No. of Patients (%) [†]			
	Overall (115 patients)	WIA (82 patients)	NBI (18 patients)	KIA/DOW (15 patients)
helmet				
worn	73 (63.5)	61 (74.4)	6 (33.3)	6 (40.0)
not worn	10 (8.7)	4 (4.9)	4 (22.2)	2 (13.3)
unknown	32 (27.8)	17 (20.7)	8 (44.4)	7 (46.7)
flak vest				
worn	77 (67.0)	63 (76.8)	6 (33.3)	8 (53.3)
not worn	9 (7.8)	3 (3.7)	4 (22.2)	2 (13.3)
unknown	29 (25.2)	16 (19.5)	8 (44.4)	5 (33.3)
ceramic plates				
worn	75 (65.2)	61 (74.4)	6 (33.3)	8 (53.3)
not worn	10 (8.7)	4 (4.9)	4 (22.2)	2 (13.3)
unknown	30 (26.1)	17 (20.7)	8 (44.4)	5 (33.3)
eyewear				
worn	60 (52.2)	50 (61.0)	4 (22.2)	6 (40.0)
not worn	16 (13.9)	9 (11.0)	5 (27.8)	2 (13.3)
unknown	39 (33.9)	23 (28.0)	9 (50.0)	7 (46.7)
mean (\pm SD)	2.5 \pm 1.8	2.9 \pm 1.7 [‡]	1.2 \pm 1.8	1.9 \pm 1.9
no. of equipment types				

* SD = standard deviation.

[†] Unless otherwise indicated.[‡] Significantly different from NBI and KIA/DOW groups.

Twelve patients (17%) with TBI had been discharged from the military during the follow-up period. A higher percentage of patients with moderate to severe TBI than those with mild TBI had been discharged (28% vs 14%), and early discharge was more likely among patients with moderate to severe TBI. The severity groups differed in their reasons for discharge: most of the patients with mild TBI were discharged due to end of obligated service and miscellaneous administrative reasons, whereas discharges among patients with moderate to severe TBI were all disability related. None of the discharges in either TBI group was due to disciplinary or behavioral misconduct, and all were honorable discharges.

There were 49 hospital admissions among 24 individuals during the follow-up period (including those occurring immediately after the injury). The number of admissions ranged from 1 to 8. As shown in Table 5, for the group as a whole, there was a mean of 2.1 admissions, 22 total bed days across all admissions, and ~ 12 inpatient diagnoses across all admissions. These admission characteristics varied by TBI group. Patients with mild TBI had slightly fewer admissions, a fewer number of bed days, and fewer diagnoses than the patients with moderate to severe TBI. Inpatient diagnoses were numerous and varied—there were 310 diagnoses across admissions and patients. Among the most common were postconcussion syndrome, fracture of the base of the skull, and injury to the optic nerve (data not shown).

There were 1166 outpatient visits by 54 patients during the follow-up period, ranging from 1 to 97 per patient. As shown in Table 5, the mean number of outpatient visits was higher among patients with moderate to severe TBI (38 visits) than among patients with mild TBI (15.5 visits).

TABLE 5
Follow-up of surviving patients with TBI overall and by TBI severity category*

Characteristic	Value		
	Overall (69 patients)	Mild TBI (51 patients)	Moderate to Severe TBI (18 patients)
% discharged	17	14	28
attrition status (%)			
early discharge	6	2	17
normal discharge	26	28	22
still on active duty	68	71	61
reason for discharge (%)			
end of service/administrative	58	71	0
disability related	42	29	100
mean no. of hospital admissions	2.1 ± 1.6	2.0 ± 2.3	2.1 ± 0.9
median	2	1	2
mean no. of bed days	22.0 ± 27.7	13.0 ± 24.9	27.0 ± 28.9
median	7	6	22
mean no. of inpatient diagnoses	12.4 ± 11.3	9.6 ± 12.4	14.6 ± 10.4
median	8	5	12
mean no. of outpatient visits	22.0 ± 23.7	15.5 ± 17.5	38.1 ± 29.7
median	14	10	32
mean no. of outpatient diagnoses	55.0 ± 64.7	38.8 ± 45.7	94.1 ± 87.9
median	34	21	66
broad outpatient diagnostic category (% diagnoses)			
influencing health signs/contact w/ health services	30	33	28
injury & poisoning	19	17	20
nervous system disease	13	14	13
musculoskeletal system	12	12	11
ill-defined symptoms/signs	11	7	15
mental disorders	5	9	1
external cause of injury	4	4	5
digestive system disease	2	1	2
infections/parasitic disease	1	<1	2
skin disease	1	<1	2
circulatory system disease	<1	<1	<1
respiratory system disease	<1	<1	<1
genitourinary system disease	<1	<1	<1
endocrine, nutrition, & metabolism	<1	<1	<1
neoplasms	<1	<1	<1
blood disease	<1	<1	<1
congenital anomalies	<1	<1	<1
% PTSD diagnoses	2	2.5	0.2

* Mean values are presented ± SDs.

The number of outpatient diagnoses was also related to TBI severity (39 and 94 diagnoses among patients with mild and moderate to severe injuries, respectively). The type of outpatient diagnoses varied somewhat by TBI severity, as shown by the broad diagnostic categories in Table 5. Mental conditions showed the largest discrepancy by TBI severity, with a higher percentage of mild TBI cases (9%) than moderate to severe cases (1%) receiving this diagnosis.

The specific diagnosis for PTSD (ICD-9-CM code 309.81) was examined, either as a primary or secondary diagnosis. There were 40 PTSD diagnoses, 37 of which were among 8 patients with mild TBI. The PTSD diagnoses comprised a larger percentage of all diagnoses among patients with mild TBI (2.5%) than among those with moderate to severe TBI (0.2%). Several social and performance-related variables among the TBI groups were also examined, including demotions, desertions, absent without leave, and divorce. There were no occurrences of these events among the patients with TBI during the follow-up period.

A final set of analyses were conducted to assess whether individuals who sustained nonbattle injuries used medical facilities and services to the same degree as those wounded in action. Because the 2 groups differed significantly in their injury severity (see Table 3), the severity had to be controlled for in the analysis. Multiple linear regressions indicated that, after adjusting for injury severity, nonbattle injuries and battle injuries did not differ significantly in terms of number of inpatient diagnoses, number of outpatient diagnoses, and number of outpatient visits (data not shown). The number of hospital admissions and number of bed days could not be examined because of the small sample sizes.

Discussion

The direct and indirect costs of TBI are substantial. In past conflicts, head wounds accounted for the greatest number of combat deaths,⁴ and acute and long-term disability was not uncommon. This descriptive study of TBIs

among personnel in OIF2 is one of the first to report TBI data collected starting at the point of injury, and including patients diagnosed with TBI who returned to duty from a Level 1 or 2 MTF.

Those injured in battle (versus those not injured in battle) were at risk for a TBI, multiple TBI diagnoses, a greater number of all diagnoses, more severe TBIs, and being evacuated for their injury. However, our analyses indicated that, after controlling for TBI severity, those wounded in battle and those wounded in nonbattle situations did not differ in their health care utilization. Although intracranial injuries (for example, concussions) were the predominant type of TBI overall and by casualty type, TBIs resulting from fractures of the skull were not insignificant among those injured in battle.

In the present study, IEDs were responsible for far more TBI diagnoses among those wounded in action and killed in action than any other mechanism of injury, including bullet wounds. The importance of IEDs has been documented in studies conducted during other OIF time frames,²³ and has been implicated as the primary cause of injury to the head and neck in Iraq.²² Emerging enemy tactics, such as the use of IEDs, call for the development of improved protection for combatants' vulnerable head region. Most patients with TBI were documented to have been wearing helmets at the time of injury, and the efficacy of the Kevlar helmet in preventing penetrating head injury is well accepted.²² However, TBI may occur without a penetrating wound, and in fact, intracranial injuries without a penetrating head wound accounted for a significant amount of injury in the present study.

About two thirds of patients with TBI overall were documented to have been wearing protective equipment at the time of injury; ~75% of those wounded in action were wearing protective equipment. Previous analyses conducted by the Navy–Marine Corps CTR found that utilization of protective gear was related to the type of artillery involved—100% of those involved in direct fire were wearing protective gear (unpublished data). The utilization rate seen in the present study is probably a result of inclusion of patients involved in both direct and indirect fire.

Traumatic injuries in general tend to involve multiple sites of injury,²² a finding that was seen in the present study of patients with TBI from the battlefield. Patients' associated injuries were typically to the face, as one would expect given the proximity of the face, head, and brain. Concomitant injuries to extremities also were common (31%). It appears that the widespread use of body armor has prevented thoracic and abdominal injuries. However, wounds to unprotected regions such as the upper and lower extremities remain a problem.

A large percentage of patients with TBI returned to duty from Level 1 and 2 MTFs—46% of those wounded in action returned to duty, and 67% of those receiving a nonbattle injury returned to duty. Although encouraging, even mild TBI has implications for unit readiness (unpublished data). Furthermore, the sequelae of a TBI may be delayed,⁹ and therefore, a TBI might not be diagnosed until sometime after the initial trauma. Patient disposition in the present study may not reflect the ultimate outcome of the patient. Long-term tracking of patients with TBI in the Navy–Marine Corps CTR, including those who returned to duty, would be useful for assessing the delayed effects of TBI.

The Navy–Marine Corps CTR is expanding its capability to track patients through convalescent care in Navy hospitals,⁷ a capability that will add to our knowledge about subsequent outcomes for those sustaining brain injuries during combat.

Follow-up of surviving patients with TBI indicated that discharge rates, number of hospital admissions, number of bed days, number of outpatient visits, and the number of inpatient and outpatient diagnoses varied by TBI severity, with the more severe patients having higher rates of morbidity and medical utilization. This finding is not surprising, although the distribution of the types of outpatient diagnoses by TBI severity was somewhat unexpected. Mental conditions in general, and PTSD diagnoses specifically, were relatively more frequent among patients with mild TBI than among those with moderate to severe TBI. This finding is somewhat consistent with those of Ommaya and colleagues¹⁶ and others (D. L. Warden, unpublished data) in which the patients with mild TBI were at greater risk than those who were more severely injured for certain service-related and medical outcomes. Patients sustaining even a mild TBI should be monitored after injury for development of problems, including mental disorders.

The Navy–Marine Corps CTR is one of the first successful attempts to collect trauma data from the combat theater so close to the time of injury. In addition, it also captures information about patients who returned to duty, currently a large but poorly understood population in the literature. Obtaining a complete description of patients injured, particularly those injured in battle, is a formidable task. Although the clinical information is quite comprehensive, information about the circumstances of injury is often incomplete because of the high occurrence of partial records. Although it is thought that the Navy–Marine Corps CTR's completeness of coverage of injuries, particularly battle injuries is good, it is very likely that the number of actual TBIs suffered by Marines during this period is much higher than our 115 cases would indicate. In addition, follow-up data from CHAMPS (those from outpatient visits) is likely to underrepresent TBI-related health care utilization because not all medical treatment facilities (battalion aid station in-garrison clinics) report visits and diagnoses to automated medical information systems. The incidence of TBI could not be calculated because the average population at risk during the time period is not known. With regard to the follow-up analysis, a longer observation period would have been useful to examine protracted outcomes of TBI. The Navy–Marine Corps CTR plans to conduct additional follow-up studies of this group of patients with TBI.

Conclusions

Despite these limitations, data from the Navy–Marine Corps CTR provide useful information about combatants' TBIs identified early in the combat casualty process. Body armor technology has reduced penetrating injuries and blasts that would have been fatal in previous conflicts;¹¹ however, the devices may not protect against impacts that can cause brain injury. Most TBIs among civilians are preventable; even in combat situations modification of the environment, early diagnosis, and appropriate care may reduce the incidence and severity of TBI. Continued careful

monitoring of the extent and circumstances surrounding this type of injury will help improve clinical care for those affected and suggest strategies for primary prevention.

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14. ABSTRACT (maximum 200 words)

Background: The purpose of this study was to characterize traumatic brain injuries (TBIs) among military personnel (primarily Marines) during the second phase of Operation Iraqi Freedom from early in the medical care chain of evacuation through Landstuhl Regional Medical Center, a Level 4 American hospital in Germany.

Methods: Data came from the Navy-Marine Corps Combat Trauma Registry (CTR), and included both battle injuries (BIs) and nonbattle injuries (NBIs). Follow-up of TBI patients was conducted to examine the short-term medical and personnel-related affects of TBI among those surviving.

Results: Those injured in battle were more likely than nonbattle cases to have multiple TBI diagnoses, a greater number of all diagnoses, more severe TBIs, and to be medically evacuated. Intracranial injuries (eg, concussions) were the predominant type of TBI, although skull fractures and open head wounds were also seen. Improvised explosive devices were the most common cause of TBIs among BIs; blunt trauma and motor vehicle crashes were the most common causes among NBIs. Short-term follow-up of surviving TBI patients indicated higher morbidity and medical utilization among the more severe TBI patients, although mental conditions were higher among milder TBI cases.

Conclusions: Data from the Navy-Marine Corps CTR provide useful information about combatants' traumatic brain injuries identified early in the combat casualty process. Results may inform clinical care for those affected and suggest strategies for primary prevention. CTR staff plans to conduct additional follow-up studies of this group of TBI patients.

15. SUBJECT TERMS

traumatic brain injury, Navy-Marine Corps Combat Trauma Registry, Operation Iraqi Freedom

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